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# A Building Stone Assessment of sandstone in Iona Nunnery and at Carsaig quarry on Mull

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*Front cover*

A window opening in Iona Nunnery formed of dressed sandstone blocks from Carsaig quarry on Mull.

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# A Building Stone Assessment of sandstone in Iona Nunnery and at Carsaig quarry on Mull

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# Contents

## FIGURES



## TABLES



# Summary

This report presents the outcomes of a project commissioned by Historic Scotland to determine, using a combination of archival records and geological evidence, whether blocks of sandstone in Iona Nunnery (a Scheduled Monument on the island of Iona) came from Carsaig quarry (a long-disused quarry on the south coast of Mull). The report also considers the feasibility of sourcing new stone to use in future repairs to the nunnery from Carsaig quarry and from the remains of nearby Carsaig pier. Details of the most suitable commercially available stones from elsewhere in the UK are also provided, should it prove not possible or not practical to obtain new stone from Carsaig quarry or Carsaig pier.

# 1 Introduction

The British Geological Survey (BGS) has been commissioned by Historic Scotland (HS) to investigate the source of sandstone blocks used in the construction of Iona Nunnery and to provide advice on sourcing suitable stone to use in repairs to the nunnery. Historic Scotland has indicated that the sandstone probably was sourced from Carsaig quarry on Mull, but the evidence is not robust. With this in mind, the objectives of the project are to:

- establish whether the sandstone used in Iona Nunnery came from Carsaig quarry, using a combination of archival records and geological evidence;
- assess the feasibility of sourcing new stone from Carsaig quarry or from the remains of nearby Carsaig pier (which is believed to be constructed of Carsaig sandstone);
- identify the most suitable commercially available stone to use in repairs, should it prove not possible or not practical to obtain new stone from Carsaig quarry or Carsaig pier.

The work presented in this report was undertaken by the BGS Building Stones team. Luis Albornoz-Parra (BGS) visited Iona Nunnery and Carsaig quarry over two days in February 2014; he was accompanied by Michael Burgoyne (Historic Scotland District Architect). Emily Tracey (BGS) conducted a brief desktop review of archival records.

A description of the visited sites is presented in section 2 of this report, and the outcomes of the archival research are described in section 3 and in appendices 1 and 2. The geology of Carsaig quarry and evidence of quarrying at the site are described in section 4, and the character of sandstone blocks used in Iona Nunnery is described in section 5. The outcomes of a brief comparison of the geological character of sandstone samples from Carsaig quarry and Iona Nunnery are described in section 6, and an assessment of potential sources of suitable stone to use in future repairs to Iona Nunnery (including Carsaig quarry, Carsaig pier, and commercially available stones from elsewhere in the UK) is presented in section 7. The key conclusions are summarised in section 8.

This project has been conducted under the Memorandum of Agreement (2011-2016) between Historic Scotland and Natural Environment Research Council (NERC, as represented by BGS).

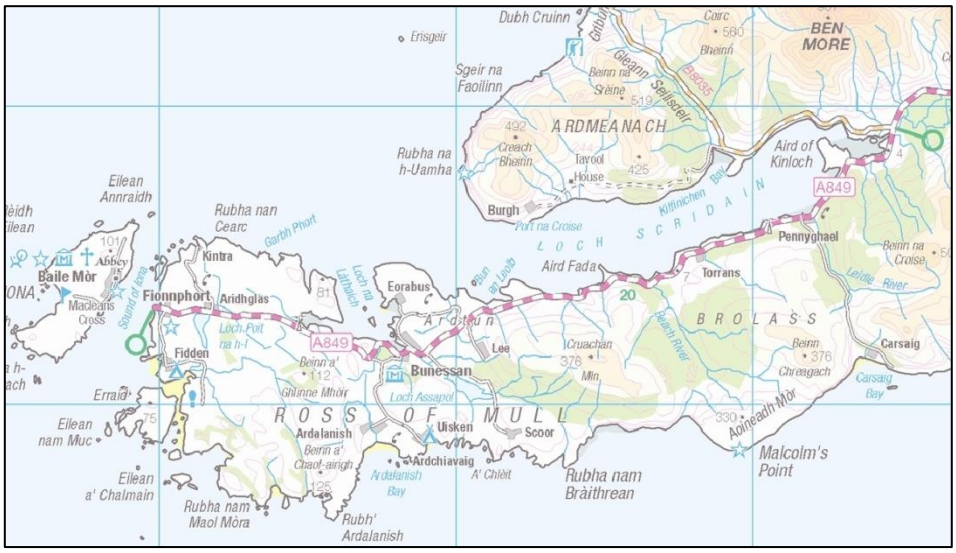



**Figure 1 Ordnance Survey map of Iona and Ross of Mull**

The island of Iona is at far left; Iona Nunnery is c. 500 metres SSW of Iona Abbey. The settlement of Carsaig is in the lower right part of the map, c. 25 kilometres from Iona Nunnery. Grid squares are 10x10 kilometres.

# 2 Site descriptions

### 2.1.1 Carsaig quarry and Carsaig pier

Carsaig quarry (NM 52521 20743) is located on the south coast of Mull, close to Rubh a' Chromain and c. 1.5 km southwest of Carsaig Bay (Figure 1, 2 and 3a). The nearest road terminates at Carsaig, c. 2 km northeast of the quarry; the quarry can be reached by a footpath from the road-end, or by sea. The Carsaig quarry site sits within the South Mull Coast site of special scientific interest (SSSI); the SSSI comprises a 17 km-long coastal strip centred on Carsaig Bay and is designated primarily on the grounds of its geological interest.

Carsaig pier (NM 54391 21296) is at the end of the road that leads to Carsaig Bay (Figure 1, 2 and 3b). The original pier is now largely ruinous; a more recently constructed section of the pier is afforded some protection from the sea by scattered blocks of stone from the original pier.

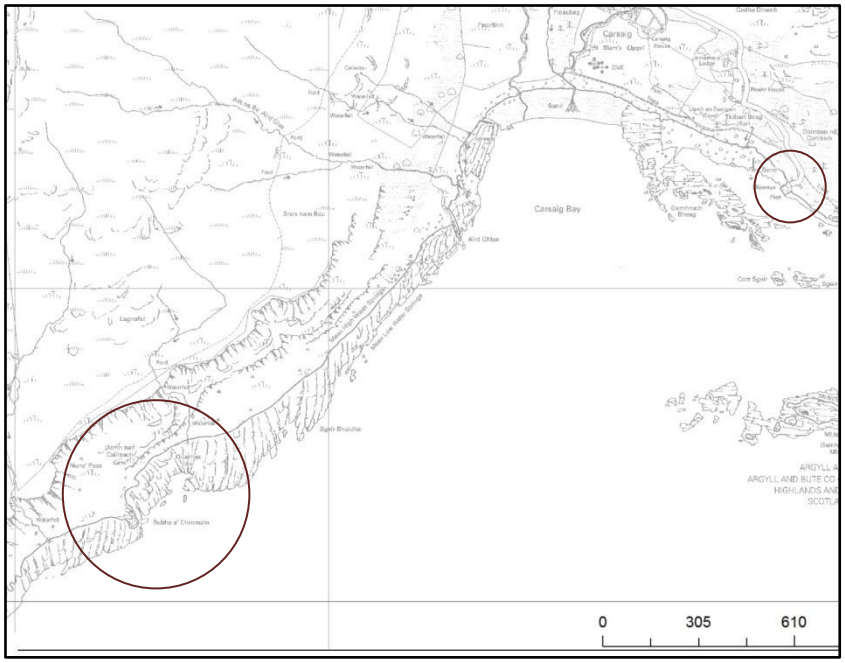



**Figure 2 1:10,000 scale Ordnance Survey map of the area around Carsaig**

The locations of Carsaig quarry (large circle) and Carsaig pier (small circle) are highlighted.

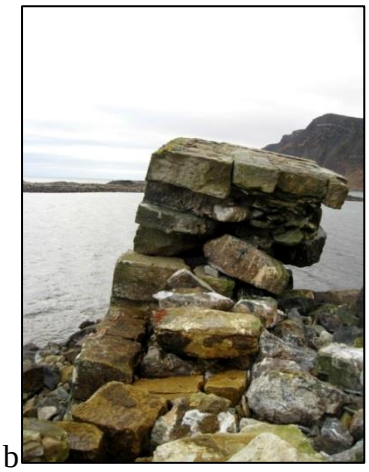
a  b 

**Figure 3 South Mull coast at Carsaig, and Carsaig pier**

a - Near Rubh a' Chromain, looking southwest; Carsaig quarry is at back right. b - The remains of Carsaig pier.

### 2.1.2 Iona Nunnery

The island of Iona is situated immediately west of the western terminus of Ross of Mull, the long peninsula forming the southern part of Mull (Figure 1). The nunnery is on the east side of the island, close to the jetty and roughly five hundred metres south-south-west of Iona Abbey.

Iona Nunnery was established as an Augustinian priory around the year 1200, and is one of the best-preserved medieval nunneries in the British Isles. The site is considered to be of national importance and is a Scheduled Monument. Since its original construction early in the 13th century there have been several well-documented interventions, in particular: a phase of partial reconstruction and enlargement at the end of the 15th century, and phases of repair in both the 19th and 20th centuries. Today, the church and associated conventual buildings are a well-tended ruin, consisting of a courtyard surrounded by buildings in an Irish Romanesque style of construction.

Several types of stone have been used in Iona Nunnery, and the various stages of building and repair commonly can be distinguished by the proportions of stone types in the walling. A detailed assessment of the building stones used at the site is beyond the scope of this project, but a brief examination has shown the following (Figure 4).

- The original walls consist dominantly of metamorphic rocks (ranging from grey to brown metasedimentary and meta-igneous rocks pinned by smaller pieces of dark grey and flaggy metasedimentary rocks). This stone almost certainly would have been sourced from local outcrops of the Lewisian Gneiss Complex and Iona Group, which form most of the bedrock on Iona. Blocks of pink granite, almost certainly from the Ross of Mull granite intrusion (which crops out on the Ross of Mull coast facing the east side of Iona), occur rarely in the earliest walls, but it is not clear if they were inserted as part of the original construction or during repairs.
- Walls constructed during the 15th century are dominated by blocks of pink Ross of Mull granite, with a smaller proportion of metasandstone blocks. Thin pieces of dark grey flagstone and at least one instance of West Highland slate (probably from the Easdale area in Argyll) are used as pinnings. Walls that were repaired in the 19th and 20th centuries consist of broadly even proportions of the main stones used in earlier stages; much of this stone is likely to have been recycled from within the grounds of the nunnery.
- The dressing stone used in all phases of building and repair (for window and door surrounds, columns, arches, quoins, and other architectural ornamentation) consists of light grey to light yellow sandstone.

## Figure 4 A typical wall in Iona Nunnery

The lower third of the wall, which consists mainly of grey metamorphic rocks, may represent part of the original (c.1200) construction. The upper two thirds of the wall, which is dominated by blocks of pink granite, almost certainly dates from a later (probably 15$^{th}$ century) phase of (re)construction. Blocks of pale sandstone have been used as dressings on either side of the window opening and around the top part of the arched doorway at the left side of the photograph.

# 3 Evidence from archival records linking Iona Nunnery and Carsaig quarry

A brief desktop assessment of archival records has been undertaken to determine if Carsaig quarry is identified as the source of the sandstone used in Iona Nunnery. Relevant information arising from this assessment is summarised in appendices 1 and 2. A full list of the reference sources included in the assessment is provided in the two appendices.

The earliest record found in this assessment that links Carsaig quarry to Iona Nunnery dates to 1885 (Groome, 1885; see Appendix 1) and is contemporary with the 19$^{th}$ century phase of repair to the then-ruinous nunnery. The record includes the passage " ... repair and partial restoration ... carried out in the autumn of 1874 and the spring of 1875 ... the stone for the repairs being all brought from Carsaig Quarry in Mull, whence the original materials had been obtained". Unfortunately, the source of the latter piece of information was not recorded.

More recently, the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) commented on the condition of the "yellowish-green Carsaig sandstone" dressings at Iona Nunnery "whose poor weathering-qualities have led to considerable deterioration in the condition of nearly all early carvings and mouldings" (RCAHMS, 1982; see Appendix 1). In the same record several other sites on Iona are described as being constructed with sandstone from Carsaig quarry (see Appendix 2). However, it is not clear where the evidence for these statements comes from; the information may be based on word of mouth and inference rather than a robust archival record.

The earliest record of quarrying at Carsaig found in this assessment dates to 1790, when Mills referred to "a very fine white freestone" in the southern part of Mull (Mills, 1790; Appendix 2). Freestone of "excellent quality" is again referred to in the first series of the Statistical Accounts of Scotland (Campbell, 1795; Appendix 2).

Ordnance Survey (OS) maps provide a record of changing quarry status over time (Figure 5). The first and second edition OS maps of Mull, published in 1881 and 1900 respectively, identify the site with the word 'Quarries', suggesting Carsaig quarry was active at both these dates. The reconstruction and repair work at Iona Nunnery undertaken by Robert Rowand Anderson in 1874-5 (Groome, 1885; Walker, 2000; see Appendix 1) just pre-dates the First Edition OS map, and the quarry would have been active (or recently active) at that time. The present-day OS map identifies the site of Carsaig quarry with the words 'Quarries (dis)', indicating that the site is disused and no longer active.

A hand-annotated geological field slip (from BGS archives) completed at some point between 1902 and 1912 records "cliffs of white sandstone with cannonball concretions" and sandstone with "flat alveolar weathering" at the Carsaig quarry site (Figure 6).

In summary, this brief desktop assessment of archival records has found that:

- A quarry at Carsaig was operating by 1790; no record has been found that states unequivocally that a quarry was operating before this date.
- Carsaig quarry is identified in at least one archival record as the source of stone used in the original (c. 1200) construction of Iona Nunnery. However, the record was written in 1885, nearly five centuries after construction and, unfortunately, the source of the information was not recorded; the record therefore should not be taken as unambiguous proof of the source of the stone used in the original construction.
- Carsaig quarry is identified in at least one archival record as the source of stone used in repairs to Iona Nunnery in 1884-85. The record containing this information was written at the time the repairs were completed, and appears therefore to be robust evidence.

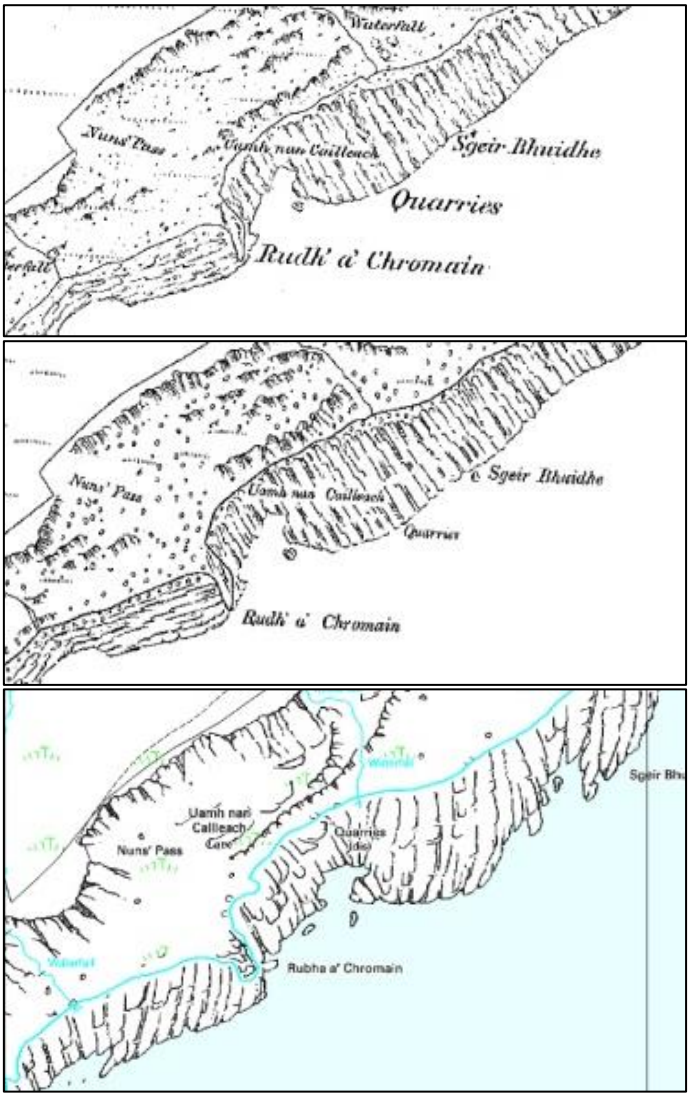



**Figure 5 Ordnance Survey maps from 1881 (top), 1900 (middle), and present day (bottom)**

The site of Carsaig quarry is indicated on all three editions (approximately in the centre of each map).

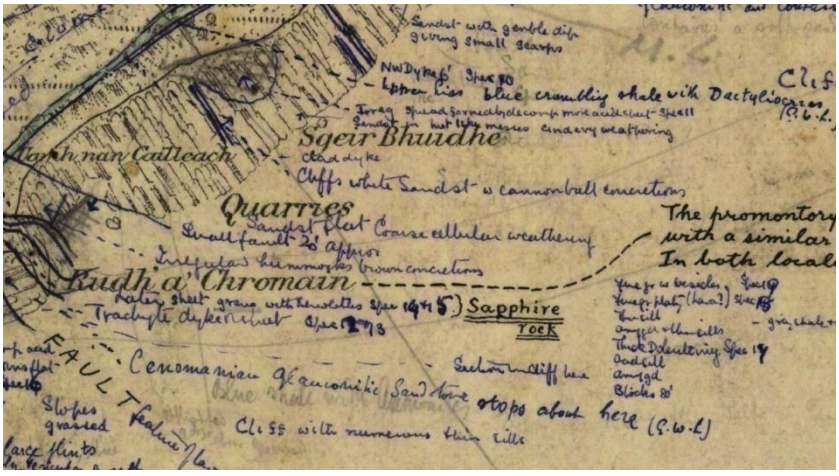



**Figure 6 Hand-annotated geological field slip completed between 1902 and 1912**

The base map is the Second edition (1900) Ordnance Survey map (BGS; see Appendix 2). Cliffs of white sandstone with cannonball concretions and sandstone with flat coarse alveolar weathering are described at the site of Carsaig quarry.

# 4 Carsaig quarry

## 4.1 GEOLOGY

The coast southwest of Carsaig Bay is lined by cliffs up to c. 200 metres high, with a narrow band of gently sloping or flat ground at their base consisting of a grassy raised beach and a rocky intertidal zone. Two sandstone-dominated geological formations crop out in the lower part of the cliffs (Figure 7): the Scalpay Sandstone Formation, which was deposited during the Early Jurassic Epoch (201–174 million years ago); and the overlying (younger) Morvern Greensand Formation, which was deposited during the Cretaceous Period (145–66 million years ago). The sandstone units sit on a 'basement' of crystalline metamorphic rocks and are overlain in the top part of the cliffs by thick beds of lava (Figure 7). The sandstone strata are essentially flat-lying (i.e. they display little or no dip), and individual beds range in thickness from c. 30 centimetres up to c. 2 metres in places. The sandstone in thinner beds is typically flaggy (i.e. it breaks naturally into thin layers along bedding-parallel joints) while sandstone in the thicker beds is typically uniform (i.e. joints are rare, and the stone naturally forms large, irregular blocks).

The Morvern Greensand Formation consists of white to very light green calcareous sandstone. Some of the stone contains glauconite (a green mica-like mineral), and this is likely to be responsible for the light green tinge. The stone locally contains gritty beds and calcareous nodules up to cobble size, and it can be conspicuously shelly (mainly oyster shells).

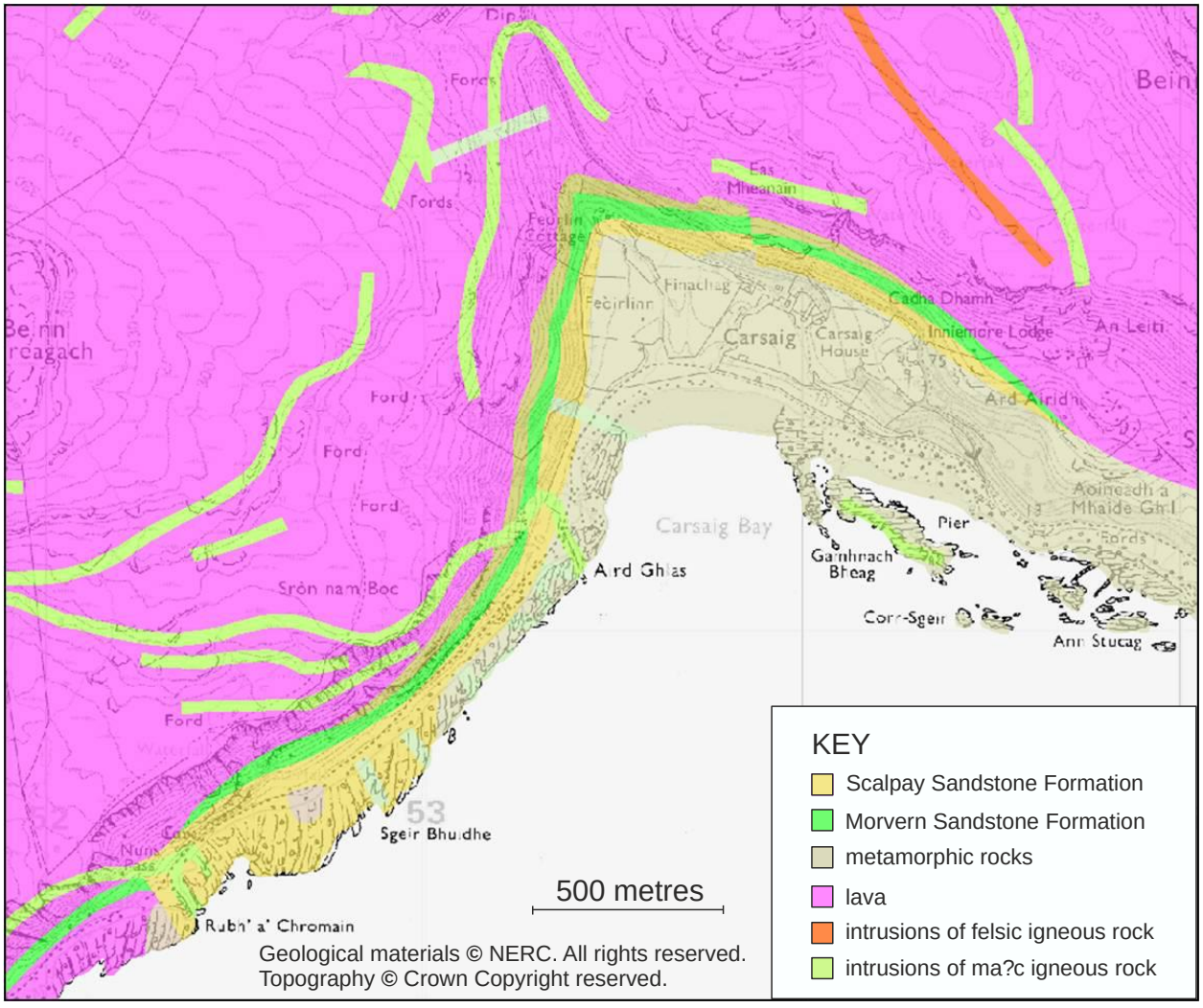



**Figure 7 Geological map of the coast in the vicinity of Carsaig**

From the BGS Digital Geological Map of Great Britain.

## 4.2 QUARRIED SITES

Evidence for quarrying was identified at three different locations during a brief assessment of the Carsaig quarry site; these are referred to below as 'cliff-face', 'Nun's Cave' and 'foreshore'. All three are interpreted to be in the Scalpay Sandstone Formation.

### 4.2.1 Cliff-face

An extensive area of sandstone cliff-face is exposed at the back of the raised beach platform at the Carsaig quarry site (Figure 8). The sandstone beds exposed in the cliff are between 1 and 1.6 metres thick and typically consist of uniform sandstone. Weathered tool marks on the lower part of the face (Figure 9) are unambiguous evidence of historical quarrying at this location.

### 4.2.2 Nun's Cave

Nun's Cave ('Uamh nan Cailleach' on figures 5 and 6) is at the base of the cliffs around 100 metres southwest of the 'cliff-face' part of Carsaig quarry, and can be accessed along the coastal path. There is no unambiguous evidence for quarrying (e.g. tool marks) at this locality, but the stone immediately adjacent to the cave has a clean, somewhat unnatural appearance suggesting it may have been worked in the past (Figure 10). Individual beds at Nun's Cave range from c. 30 centimetres thick (these would have produced blocks of flaggy sandstone) to more than 1 metre thick (these would have produced blocks of uniform sandstone). The cave is situated in the same sequence of sandstone beds as the tool marks at the 'cliff-face' exposure (see above).

### 4.2.3 Foreshore

A sequence of interbedded sandstone and mudstone layers in relatively thin beds is exposed in the foreshore (intertidal) area of the Carsaig quarry site (Figure 11). The beds of sedimentary rock dip gently towards the cliff, so this part of the sequence is stratigraphically below the beds exposed in the 'cliff-face' and 'Nun's Cave' areas. Beds of sandstone up to c. 1 metre thick are separated by thinner layers of relatively soft brown mudstone. Though no direct evidence of quarrying (e.g. tool marks) was observed, this intertidal area has a flat and somewhat unnatural appearance. The sandstone would have been relatively easy to prise out of the softer mudstone layers and it seems likely that blocks of sandstone have been removed extensively from this area.

## 4.3 STONE CHARACTER

Prior to this project the BGS Rock Collection included one hand sample of stone from Carsaig quarry (BGS sample S54103), with an accompanying thin section. The sample was probably collected during early (1900-1912) geological surveying of the area. The precise locality of the sample is not recorded (the label reads 'Carsaig Quarry'), but it is likely to come from the 'cliff-face' part of the quarry, as this is the most obviously quarried site. Two other hand samples (BGS samples ED11280 and ED11281) were collected during the current site visit from the lower, accessible part of the quarried cliff-face. All three 'cliff-face' samples are fine- to medium-grained, quartz-rich, uniform sandstone that is very light grey when fresh (sometimes with a green tinge) and with a superimposed faint to strong yellow or orange tinge depending on the degree of weathering. The stone shows no reaction to a solution of dilute hydrochloric acid and therefore appears to contain no calcite. A petrographic description of sample S54103 is presented in Appendix 3.

The fresh sandstone at Nun's Cave is in general closely similar to the 'cliff-face' stone (the two sites are situated in the same sequence of sandstone beds) but differs slightly in some details, being very light grey (almost white), fine-grained and strongly cohesive (harder than the 'cliff-face' stone). A sample was not collected from this location as it is difficult to sample discreetly from the bedrock, and at the time of the visit there were no detached blocks of reasonably fresh stone in the vicinity.

Sandstone exposed in the 'foreshore' area is in most respects closely similar to the 'cliff-face' sandstone, but the stone typically is slightly finer grained and commonly contains faint cross-lamination on a mm- to cm-scale; where the stone contains significant cross-lamination it typically has a darker (brownish) colour. The stone here is also typically calcite-bearing (i.e. it typically reacts to a solution of dilute hydrochloric acid). Two hand samples (BGS samples ED11282 and ED11283) of sandstone were collected from the foreshore area during the current site visit. A petrographic description of sample ED11283 is presented in Appendix 3.

**Figure 8 The cliff-face part of Carsaig quarry, looking north**

The stone presumably was quarried mainly from the lower levels of the cliff. Sample ED11280 was obtained from the base of the cliff at the right side of the photograph, and sample ED11281 from the base of the cliff to the left, just out of picture. A horizontal band of sandstone containing prominent, evenly spaced, ovoid, metre-scale concretions (chemical concentrations of mineral cements) appears at mid-height on the cliff face.

**Figure 9 Weathered tool marks on the 'cliff-face' part of Carsaig quarry**

The photo includes two beds of sandstone in the Scalpay Sandstone Formation; the boundary between the beds is marked by a horizontal line just above the lower set of tool marks. The lower bed is c. 1.7 m thick and consists of massive sandstone. The weathered surface of the stone is covered by a thin film of dark grey algae and lichen but the fresh, interior stone is very light yellow and white. Hammer included for scale.

**Figure 10 The entrance to Nun's Cave**

The roof of the cave is in a band of flaggy sandstone while the beds above and below are uniform sandstone.

**Figure 11 The foreshore at Carsaig quarry, looking northeast**

The exposed bedrock consists of interbedded sandstone and mudstone. Much of the sandstone appears to have been stripped from the foreground part of this image, leaving mainly grey mudstone and thin beds of sandstone. The 'cliff-face' part of Carsaig quarry is in the left background of the photo.

# 5 Sandstone in Iona Nunnery

The importance of Iona Nunnery as a heritage building means it was not possible to collect samples of stone from *in situ* blocks, or to chip block surfaces to see the fresh stone beneath; it also was not possible to conduct a test for the mineral calcite using dilute hydrochloric acid on *in situ* blocks. Furthermore, all of the sandstone blocks in Iona Nunnery are weathered to some degree; block surfaces generally have lost most or all of their original detail (relict droving is faintly visible in some cases) and are discoloured to varying degrees by a patina of biogenic growth and soiling. Some blocks have been substantially eroded.

For the reasons stated above it is difficult to make a detailed assessment of the character of the sandstone in Iona Nunnery. However, even though only a brief assessment was possible, it is clear that the general character of the stone is closely similar to the stone at Carsaig quarry. The sandstone is generally grey to light yellow on weathered surfaces, typically fine- to medium-grained, usually quartz-rich, and can be uniform or weakly irregularly laminated.

Blocks of sandstone have been used in several ways in Iona Nunnery.

- Rubble blocks of sandstone have been used as loose 'filling' in thick walls (Figure 12a). This sandstone has the macroscopic characteristics of stone from the 'foreshore' part of Carsaig quarry (i.e. it is generally brownish grey with irregular lamination, and is calcite-bearing). Two loose cobbles from the filling in the wall separating the nave and the aisle were collected as hand samples (BGS samples ED11284 and ED11285).
- Dressed blocks of sandstone have been used to form window and door surrounds, quoins, arches, columns and gutters (Figure 12b-d and Figure 13). This stone may occur in two main variants – generally grey, weakly weathered blocks and generally light yellow, more strongly weathered blocks. Thin, quartz-rich 'veins' (possibly small geological faults known as 'granulation seams') occur in a few blocks of the grey stone[1] (Figure 12d). The grey blocks seem to occur mainly in the oldest, probably mainly original, parts of the nunnery (e.g. in the lower sections of walls, beneath reconstructed parts), and the light yellow blocks seem to occur mainly in later phases of reconstruction and repair. However, this observation should be treated with caution due to the briefness of the visit, the weathered condition of the stone, and the likelihood that some blocks have been recycled in the various phases of building and repair. The macroscopic geological character of dressed blocks encompasses the full range of character observed at Carsaig quarry. Many blocks have the character of stone at the 'cliff-face' and 'Nun's Cave' parts of Carsaig quarry, but a very small fragment (BGS sample ED11286) that previously had broken off a piece of dressed stone on the arched doorway between the cloister and the nave, and was lying on the ground, has essentially the same character as the rubble blocks suggesting that stone from the 'foreshore' part of the quarry forms some dressed blocks.
- Blocks of sandstone that have an 'L' shape in profile have been used to form a bench in the Chapter House (Figure 14). The stone forming these blocks is largely concealed beneath a covering of lichen, but close inspection suggests it generally has the macroscopic character of stone from the 'cliff-face' part of Carsaig quarry.

The client has indicated that a damaged part of the stone bench in the Chapter House is likely to be the subject of the first repair that will follow the publication of this report. The bench is constructed of 'L-shaped' blocks of sandstone, each of which has one end set into the adjacent wall. A typical block has dimensions of c. 80 x 36 (the horizontal 'seat' surface) x 22 (thickest part of the vertical dimension, which is set into the wall) centimetres; this obviously constrains the minimum size of a block of new stone that could be used to replace a damaged block.

[1] Quartz-rich veins and/or granulation seams were not observed at Carsaig quarry, but they are likely to be developed intermittently in the rock mass and would not necessarily be visible on the rock faces exposed at the quarry today.

## Figure 12 Typical appearance and uses of sandstone in Iona Nunnery

In image ‘a’ the block on which the hand lens rests and the similarly coloured block above it are sandstone. The other blocks are different rock types. In image ‘d’ two blocks of grey, relatively weakly weathered sandstone are separated by two blocks of yellow, more strongly weathered sandstone in a column of sandstone blocks. The lowest block contains a prominent diagonal quartz-rich vein or granulation seam.

**Figure 13 Dressed window surrounds and rubble walling, the refectory**

The lowest three blocks on each side of the window opening are light grey, fine-grained, strongly cohesive sandstone, which is in generally good condition (weakly weathered). The dressed blocks around the top part of the opening are yellowish, fine- to medium-grained sandstone which is in comparatively poorer (more strongly weathered) condition. The boundary between the two coincides broadly with a change in character of the adjacent walling stone: the lower half of the wall is dominated by blocks of grey metamorphic rock while the upper half is dominated by blocks of pink granite. It seems likely that the lowest blocks of sandstone are part of an earlier (possibly the original) phase of building, while the upper blocks of sandstone are part of a later reconstruction.

**Figure 14 Stone bench in the Chapterhouse**

The remains of the Chapter House form the foreground. A line of protruding blocks of sandstone, forming a stone bench, is embedded into the low wall in the middle distance. The whiteness of the bench is due to lichen.

# 6 Petrographical assessment

The evidence from archival records presented in section 3 of this report provides proof that stone used in some of the later (19th century) repairs to Iona Nunnery was sourced from Carsaig quarry, and also provides a strong (though not unambiguous) indication that the stone used in the original (c. 1200) construction was sourced from Carsaig quarry. A comparison of the geological character of stone at both sites has been undertaken to complement the review of records.

Some comments have already been made in sections 4 and 5 regarding the geological character of sandstone at Carsaig quarry and Iona Nunnery, and how the sandstone at both sites compares. Even though only weathered surfaces can be examined, blocks of sandstone at the nunnery appear to display the full range of character observed at Carsaig quarry.

Samples of sandstone were collected from both the quarry and the nunnery to enable a petrographical assessment. Unfortunately, because the quarry sits within an SSSI and the nunnery is a Scheduled Monument it was not possible to collect samples that represent the full range of stone at each site; in particular, it was not possible to collect a sample from the 'Nun's Cave' part of the quarry, and samples from the nunnery could only be collected from rare detached fragments of stone.

Details of the stone samples that were collected as part of this study are summarised in Table 1. A thin section (a slice of stone thin enough to be transparent so that it can be examined using a transmitted light microscope) has been prepared from three of these samples. Table 1 includes details of a further sample of stone from Carsaig quarry (S54103) that was already held in the BGS Rock Collection. A petrographical description for each of the four samples for which there is a thin section is presented in Appendix 3; the descriptions are based on visual (macroscopic) examination of hand samples and microscope examination of the thin sections.

The hand samples have the advantage that they present relatively fresh stone surfaces for examination, and a simple unaided visual assessment of the hand samples confirms the overall similarity of character of sandstone from both sites. The key conclusions of the assessment of thin sections can be summarised as follows.

- The sample from the 'cliff-face' area of Carsaig quarry (S54103) is fine- to medium-grained and quartz-rich (c. 74%), with only very small proportions of other detrital minerals (total c. 5%). Of the intergranular constituents, silica overgrowths are moderately well developed (c. 4%), but carbonate minerals (including calcite) are essentially absent.
- The sample from the 'foreshore' area of Carsaig quarry (ED11283) is fine-grained and moderately quartz-rich (c. 64%), with small proportions of other detrital constituents (total c. 7%). Of the intergranular constituents, silica overgrowths are weakly developed (c. 2%), and both carbonate minerals (mainly or entirely calcite) and iron oxide are relatively abundant (c. 7% and 5%, respectively).
- The thin section characteristics are consistent with the hand specimen observations. The slight but distinct variability in character reflects the different environments during deposition of the sediments that now are exposed in the 'foreshore' and 'cliff-face' parts of Carsaig quarry.
- All three samples collected from the nunnery share similar macroscopic characteristics, and these in turn are closely similar to those of the sample from the 'foreshore' part of the quarry. The corresponding thin sections (sample ED11283 from Carsaig quarry foreshore area) and ED11286 (from an arched doorway at Iona Nunnery) are virtually identical, in terms of both their individual mineral-textural characteristics and their overall appearance in thin section (see Appendix 3). The similarity is so close that there can be little doubt that the stone from the nunnery came originally from Carsaig quarry.

| BGS sample no. | Sample locality | Summary hand sample description | Thin section |
|---|---|---|---|
| **S54103** | Carsaig quarry, probably from the cliff-face area. The sample is labelled 'Carsaig Quarry' and probably was collected during early [1900-1912] geological surveying. | medium-grained very light yellowish grey (due to weathering), uniform sandstone; no calcite | Y |
| **ED11280** | Carsaig quarry, cliff-face area | fine- to medium-grained, very light yellow (almost white), uniform sandstone; no calcite | N |
| **ED11281** | Carsaig quarry, cliff-face area | | N |
| **ED11282** | Carsaig quarry, foreshore area | fine-grained, brownish grey sandstone with irregular lamination; calcite present | N |
| **ED11283** | Carsaig quarry, foreshore area | | Y |
| **ED11284** | Iona Nunnery; a loose cobble from 'filling' in the wall between the nave and the aisle. | fine-grained, brownish grey sandstone with faint irregular lamination; calcite present | N |
| **ED11285** | Iona Nunnery; a loose cobble from 'filling' in the wall between the nave and the aisle. | | N |
| **ED11286** | Iona Nunnery; a small fragment of stone on the ground beneath the arched doorway between the cloister and the nave; assumed to be from the doorway. | fine-grained, brownish grey sandstone with faint irregular lamination; calcite present | Y |
| **ED11279 P1 to P6** | Carsaig pier; six pieces of stone from separate blocks of sandstone. | typically fine-grained, light grey to light buff sandstone (sometimes with a greenish tinge), that is generally uniform but with weak irregular lamination developed locally; calcite is present in some pieces | Y (P5) |

**Table 1 Summary details of sandstone samples collected for this study**

# 7 Sources of suitable stone to use in repairs

## 7.1 CARSAIG QUARRY

Carsaig quarry is almost certainly the source of sandstone used in Iona Nunnery; therefore, stone used in future repairs to the nunnery ideally would be sourced from the quarry. However, sourcing new stone from Carsaig quarry would be challenging for a number of reasons: the quarry site has no vehicle access and can only be reached by foot or by boat; there are no detached, sizeable blocks of suitable stone at the quarry site, so any new stone would probably have to be quarried from exposed bedrock (probably by excavating into the cliff face); the site is within an SSSI, so Scottish Natural Heritage would need to grant permission to extract stone.

## 7.2 CARSAIG PIER

Carsaig pier (Figure 1, Figure 2 and Figure 3b) was constructed in 1850 and is now largely ruinous, though part of the old pier has been repaired relatively recently. Numerous naturally formed boulders (probably mainly of igneous rock) and many squared blocks of sandstone are scattered around the remains of the pier (Figure 15). Six samples of stone were collected from different sandstone blocks at the pier (BGS samples ED11279/1-6), and a thin section of one sample (ED11279/5) was prepared. Examination of blocks at the pier, the hand samples and the thin section (see Appendix 3) has shown that the stone is closely similar in all respects to stone from the 'cliff face' and 'Nuns' Cave' parts of Carsaig quarry. This, and the close proximity of the quarry, makes it very likely that the stone used in Carsaig pier was sourced from Carsaig quarry. One of the hand samples has a greenish tinge and may have been sourced from the Morvern Greensand Formation, which overlies the Scalpay Sandstone Formation at the quarry site (see section 4.1); this block may have been sourced from a boulder of Morvern Greensand Formation that had fallen onto the foreshore between Carsaig pier and Carsaig quarry.

The stone blocks at Carsaig pier are in surprisingly good condition, given the ruinous state of the pier and its exposed location. The block surfaces typically show signs of weak weathering, but the stone beneath the thin weathered layer is generally hard and sound. The block dimensions vary somewhat, but a typical block (not the largest) measured on site was 116x72x40 cm. Some of the blocks have rusted iron bars and cramps embedded in them, but even if they were split these could still yield moderately large blocks of useable stone.

The large size, good condition, road-end location, and likely provenance of sandstone blocks at Carsaig pier means they almost certainly present the best source of replacement stone to use in repairs to the sandstone elements of Iona Nunnery. However, the size of the blocks and the fact that many are scattered in the intertidal zone means it may prove difficult to lift and move them; issues of ownership and permission would also need to be resolved.

## 7.3 COMMERCIALLY AVAILABLE STONES

If it proves not possible or not practical to obtain sandstone from Carsaig quarry or Carsaig pier, it may be necessary to use commercially available stone from elsewhere in the UK. A stone-matching exercise to identify the closest-matching commercially available stones has been performed; details of the process and the identified stones are provided in Appendix 4. The list of closest-matching stones includes stone from five different quarries: Spynie, Clashach, Cullalo, Hazeldean and Darney. Spynie and Clashach quarries are in Morayshire and the sandstone they produce is from slightly older strata than Carsaig sandstone (deposited during the Permian and Triassic periods). Cullalo quarry is in Fife, and both Hazeldean and Darney quarries are in north-east England; the stone produced by these three quarries was deposited during the Carboniferous Period and is significantly older than Carsaig sandstone.

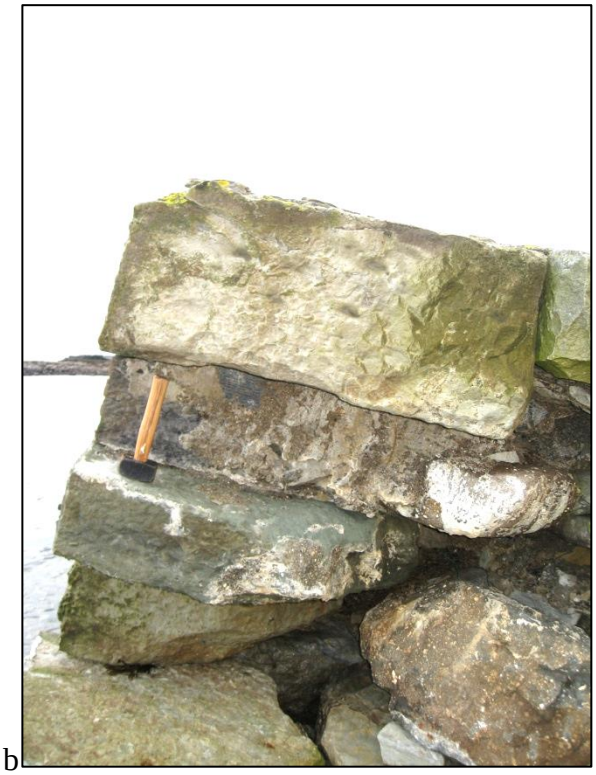
a  b 

**Figure 15 Typical blocks of sandstone at Carsaig pier**

# 8 Conclusions

This study has produced the following conclusions.

- Carsaig quarry, sited at the base of sea cliffs on the south coast of Mull, historically produced sandstone from the Scalpay Sandstone Formation, a sequence of sandstone-dominated strata that was deposited on a shallow sea floor during the Jurassic Period.
- An archival record proves that a quarry at Carsaig was operating by 1790, but no record has been found that states unequivocally that a quarry was operating before this date.
- The quarry has long been disused, but today there is evidence that stone was quarried from at least two locations: from the lower part of the cliff-face at the back of the raised beach (possibly including the area adjacent to Nun's Cave), and from the (intertidal) 'foreshore' area.
- The stone forming the cliff-face is typically fine- to medium-grained, quartz-rich, uniform sandstone that is very light grey when fresh and shows no reaction to a solution of dilute hydrochloric acid (indicating the mineral calcite is not present). Sandstone from the foreshore area is similar to the 'cliff-face' sandstone in most respects, but typically is slightly darker (brownish grey), slightly finer grained, and commonly contains faint cross-lamination on a mm- to cm-scale; the stone from this area typically also reacts to a solution of dilute hydrochloric acid (indicating that calcite forms a partial mineral cement).
- Iona Nunnery, on the island of Iona, is approximately 25 kilometres west of Carsaig quarry. The nunnery was constructed around the year 1200, extended and partially reconstructed in the 15$^{th}$ century, and repaired in the 19$^{th}$ and 20$^{th}$ centuries.
- Sandstone is a minor component of the building stone used in Iona Nunnery. Dressed blocks of sandstone have been used to form window and door surrounds, quoins, arches, columns and gutters. Sandstone blocks also comprise part of the 'rubble' filling in thick walls, and blocks of sandstone have been used to construct a bench in the Chapter House. A damaged part of the stone bench in the Chapter House is likely to be the subject of the first repair that will follow the publication of this report.
- Carsaig quarry is identified in at least one archival record as the source of stone used in the original (c. 1200) construction of Iona Nunnery. However, the record was written in 1885, nearly five centuries after construction and, unfortunately, the source of the information was not recorded; the record therefore should not be taken as unambiguous proof of the source of the stone used in the original construction.
- Carsaig quarry is identified in at least one archival record as the source of stone used in repairs to Iona Nunnery in 1884-85. The record containing this information was written at the time the repairs were completed, and appears therefore to be robust evidence.
- Sandstone exposures at the quarry and sandstone blocks in the nunnery display the same range of macroscopic characteristics. Thin sections from the foreshore area of Carsaig quarry and from an arched doorway at Iona Nunnery are virtually identical, leaving little doubt that they share the same provenance.
- Though it has not been possible to prove unambiguously that all of the sandstone used in Iona Nunnery has been sourced from Carsaig quarry, the weight of archival and geological evidence suggests strongly that this is the case. It seems likely therefore that

stone was sourced several times from Carsaig quarry to provide material for the original construction of the nunnery and the various phases of reconstruction and repair.

- Ideally, new stone to use in future repairs to Iona Nunnery would be sourced from Carsaig quarry. However, this would be challenging for a number of reasons, including difficulty of access, the absence of loose blocks at the site (which, if they were present, might provide suitable stone without the need to detach new stone blocks), and the apparent scarcity of easily detachable blocks in the bedrock currently exposed. The quarry also sits in a Site of Special Scientific Interest (SSSI), which might limit or prevent renewed recovery of stone.
- Squared blocks of sandstone scattered around the largely ruinous remains of Carsaig pier consist of stone that has the same character as stone from Carsaig quarry. This, and the close proximity of the quarry, makes it very likely that the stone used in Carsaig pier was sourced from Carsaig quarry. The large size, good condition, road-end location, and likely provenance of sandstone blocks at Carsaig pier means they almost certainly currently present the best source of small volumes of replacement stone to use in repairs to the sandstone elements of Iona Nunnery. However, the size of the blocks and the fact that many are scattered in the intertidal zone means it may prove difficult to lift and move them; issues of ownership and permission would also need to be resolved.
- It may be necessary to use commercially available stone from other parts of the UK to replace the sandstone used in Iona Nunnery, if it proves not possible or not practical to obtain sandstone from Carsaig quarry or Carsaig pier. The closest-matching commercially available stones are from the following quarries: Spynie, Clashach (white Clashach sandstone), Cullalo, Hazeldean, and Darney (Darney Cream and Darney White sandstone).

# Appendix 1 Summary information about Iona Nunnery arising from a brief review of historical records

| **REFERENCE SOURCE** | **REFERENCE DESCRIPTION** | **NOTES** (direct quotations extracted from references are *in italics*) |
|---|---|---|
| | | |
| **Archival Records, Databases** | | |
| CANMORE | RCAHMS database | Canmore ID 21621. No references to building stones. |
| Scheduled Monument List | Historic Scotland database | Index Number 90350. No information available. |
| **Reference Texts** | | |
| The Statistical Accounts of Scotland | Campbell, Dugal, Rev. "Parish of Kilfinichen and Kilviceuen, County of Synod of Argyll, Presbytery of Mull." The Statistical Account of Scotland, vol. 14, no. 12. Ed. John Sinclair. Edinburgh: William Creech, 1795. | *At the nunnery, there are fewer remains. The Nunnery Church is quite entire; one end of it is arched, and is very beautiful. Here also stands, what was called the parish church. It is yet entire, but tottering. There was a court, with a piazza, to the W. side of the Nunnery Church, and round it the cloisters were built; but there are hardly any remains of them, but on the S. side of the court.*(202) |
| The Statistical Accounts of Scotland | Campbell, Donald, Rev. "Parish of Kilfinichen and Kilviceuen, comprehending the Quoad Sacra Parish of Iona, in the Island of Mull, Presbytery of Mull, Synod of Argyle." The Statistical Account of Scotland, vol. 7, Renfrew-Argyle. Edinburgh: William Blackwood and Son, 1845. | *Nunnery--The successors of Columba did not, it would appear, adhere to his strict prohibition for the exclusion of females from the Island. We are sure there were no monastic establishments for females during the times of Columba's discipline, nor under the Culdees, The proper monastic establishments of Iona belong to the age of the Romish influence. Indeed, there were no nunneries in Scotland until the introduction of the regular Popish clergy, and, therefore the date of this building is brought down to a period later at least than 1200. The architecture is purely Norman.*<br>*The chapel has been a very neat building, and is said to have been the burial-place for ladies of high rank, as St Mary's church and Oran's chapel were for men.*<br>*At the eastern end of the chapel is the tomb of the last prioress, which is now much defaced.*<br>*There are some other monuments on the floor, but they are so defaced as to be almost undistinguishable.*<br>*This nunnery is said to have been liberally endowed; besides the islands of Inniskenneth and Eorsa formerly mentioned as belonging to the prioress, there were lands in Mull which it enjoyed, and some of which go by the name of the Nuns' lands to the present day.* (336-7) |

| **REFERENCE SOURCE** | **REFERENCE DESCRIPTION** | **NOTES** (direct quotations extracted from references are *in italics*) |
|---|---|---|
| Ordnance Gazetteer of Scotland | Groome, FH. *Ordnance Gazetteer of Scotland: a survey of Scottish topography.* Edinburgh: Grange Publishing Works, 1885. | *The deed of confirmation of the monastery, dated 9 Dec. 1203, still exists in the Vatican, and most of the ruins that now exist are those of this monastery and nunnery … At the instance of the Duke of Argyll, the ruins were in 1873 visited by Mr Robert Anderson, architect, Edinburgh, who drew up a report with suggestions for their repair and partial restoration. These were carried out in the autumn of 1874 and the spring of 1875 with the most excellent taste and judgment, the stone for the repairs being all brought from* ***Carsaig Quarry*** *in Mull, whence the original materials had been obtained.* (322) |
| Memoirs of the Geological Survey, Scotland | RCAHMS. "Mull, Tiree, Coll & Northern Argyll (excluding the Early Medieval & later monuments of IONA)". *Argyll: an inventory of the monuments, vol.3.* Edinburgh: Her Majesty's Stationery Office, 1980. | *Iona Cathedral. The older part of this Cathedral, and the Nunnery are mainly constructed of granite and flags, which are interbuilt without much dressing, but according to a definite plan. The pillars and facings are of sandstone. The granite is Ross of Mull granite, which might have been got from local boulders. In reconstructing the Cathedral the contractors followed the style of the original, and granite was obtained from teh mainland Black Island Quarry.* (124) |
| Royal Commission on the Ancient and Historical Monuments of Scotland | RCAHMS. Iona. *Argyll: an inventory of the monuments, vol.4.* Edinburgh: Her Majesty's Stationery Office, by Pillans & Wilson Ltd., 1982. | *… The remains comprise the nunnery church, together with portions of associated conventual buildings lying on the S side. The original early-13th-century layout is to a large extent preserved, and most of the existing buildings can be ascribed to this period, apart from the S and W claustral ranges, which were enlarged and rebuilt around a more spacious cloister-garth towards the end of the 15th century. Certain alterations were also made to the church at this time in order to increase the amount of accommodation and to provide an additional altar-chapel. Following the cessation of religious life in the 16th century the buildings gradually become ruinous, and remained derelict until about 1874, when the surviving portions of the fabric were repaired and consolidated; the church was partially restored in 1923.*<br>*The church itself is fairly well preserved, much of the W and N walls, together with the restored N chapel, standing almost to their original heights. The chancel-arch and the vault and most of the E wall of the chancel, however, collapsed about 1832, while the S wall of the nave and the walls of the N aisle are also reduced to their lower courses, as are those of the E range of conventual buildings. Much of the S range of the cloister stands to its full height, together with part of the inner wall of the W range and much of its internal area lie beneath the roadway that skirts the W and S sides of the site. (152-3)* |
| Royal Commission on the Ancient and Historical Monuments of Scotland | Ibid. | *The buildings [at Iona Nunnery] are constructed partly of red granite boulders and partly of dark-grey rubble comprising mainly basalt and Torridonian flagstones. The latter are readily available on the island, as for example in the outcrops on the adjacent foreshore, while the granite was probably obtained from local glacial boulders and erratic blocks. The dressings are of yellowish-green* ***Carsaig sandstone****, whose poor weathering-qualities have led to considerable deterioration in the condition of nearly all early carvings and mouldings. Some of the nunnery buildings appear to have been roofed with micaceous flags, a number of which can be seen built into the sides of the beam-sockets associated with the W nave-gallery of c.1500; these were probably quarried in the Ross of Mull.* (153) |

| REFERENCE SOURCE | REFERENCE DESCRIPTION | NOTES (direct quotations extracted from references are *in italics*) |
|---|---|---|
| Pevsner Architectural Guide | Walker, Frank Arneil. *The buildings of Scotland: Argyll and Bute*. Penguin Books: London, 2000. | *On Iona, …an Augustinian nunnery* [was] *founded before the end of the C12… The nunnery, ruinous but relatively well preserved* [at time of writing]*, comprises a nave-and-aisle church with cloister ranges again conventionally placed S.* (28) |
| Pevsner Architectural Guide | Walker, Frank Arneil. *The buildings of Scotland: Argyll and Bute*. Penguin Books: London, 2000. | *Well-tended remains of church and conventual buildings established as an Augustinian foundation c.1200: one of the best-preserved medieval nunneries in the British Isles… the layout is conventional with the cloister garth lying on the SW side of the church. Constructed in very varied rubble masonry, the ruins are considerable and much survives from the original building period. The church nave and chancel, the N aisle with its chapel, and the E range in which the chapter house was located, all date from the early C13. S and W claustral ranges were reconstructed at the end of the C15 when accommodation was increased and the cloister enlarged. Abandoned following the religious reforms of the C16, the buildings became ruinous. By the late C18 what remained was largely what stands today. In 1822-3 part of the chancel vault fell; ten years later it collapsed completely. Repairs and consolidation were carried out under Robert Rowand Anderson, 1874-5, and in 1917 Peter MacGregor Chalmers envisaged a major restoration, though the resultant works were limited to the N chapel, sacristy and cloister garden.* |
| **Internet Search** | | |
| PastMap | http://pastmap.org.uk/ | Historic Scotland Scheduled Monument, no information available |
| Google Books | McCabe, S and Smith, BJ. "Understanding the Long-Term Survival of Sandstone in Medieval Ecclesiastical Structures: Northern Ireland and Western Scotland". *Materials, Technologies and Practice in Historic Heritage Structures.* M. Bostenaru Dan, et al. (Eds.). Netherlands: Springer Science+Business Media, BV, 2010. | Section on the use of Carsaig Sandstone in Iona Abbey (not the Nunnery), and the weathering characteristics and decay patterns of the original and replacement sandstone. |

# Appendix 2 Summary information about Carsaig quarry arising from a brief review of historical records

| **REFERENCE SOURCE** | **REFERENCE DESCRIPTION** | **NOTES** (direct quotations extracted from references are *in italics*) |
|---|---|---|
| | | |
| **Archival Records** | | |
| CANMORE | RCAHMS database | The CANMORE database contains no records of quarry sites at Carsaig |
| **Reference Texts** | | |
| Philosophical Transactions of the Royal Society | Mills, Abraham. "Some account of the strata and volcanic appearances in the North of Ireland and Western Islands of Scotland". *Philosophical Transactions of the Royal Society of London, vol. 80.* London: The Royal Society, 1790. | *During our stay at Fidden, I learned from Mr. Stewart, that Rhos Mull, which is the NW part of Mull, is chiefly red granite: in the southern part of the island is a very fine white freestone, and between that and the granite all whynstone.* (84) |
| The Statistical Accounts of Scotland | Campbell, Dugal, Rev. "Parish of Kilfinichen and Kilviceuen, County of Synod of Argyll, Presbytery of Mull." *The Statistical Account of Scotland, vol. 14, no. 12.* Ed. John Sinclair. Edinburgh: William Creech, 1795. | *Rocks and Stones.-There are rocks and stones of various kind in the parish, such as marble, granite, freestone, lime-stone, moor-stone or whin-stone, flags and pebbles ... A marble quarry was opened some years ago, under the patronage of the Duke of Argyll, in the island of I, which is Grace's property. A considerable quantity of marble was quarried, and sent to Leith and London; but, after much money was laid out, the quarry was given up, for some time at least. The marble is said to be of excellent quality. The hole coast of Ross, upon the sound of I, is granite for several miles. No use is made of it, except in building farmhouses and walls. There is lime-stone in Carsaig and Gribun; but both these coasts are so dangerous for shipping, that no use is made of it. Free-stone is also found in **Carsaig** of excellent quality. Some of it is used by several gentlemen in the country for their houses. A great proportion of the rocks of Ross consists of flags, that might serve to excellent purpose for arching of bridges. The only use they are put to in the country is lintels for doors and windows, and building farm-houses and wall. Pebbles are found in the island of I, of which seals and sleeve-buttons are made.* (184-5) |
| A description of the Western Islands of Scotland | Mucculloch, John. *A description of the Western Islands of Scotland, vol. 1.* London: J. Moyes: 1819. | [At **Carsaig** Bay] *… the limestone* [cliff] *appears to terminate, but it will immediately be seen that the strata of sandstone usually associated with it are continued in the same manner, and without discontinuity, to the western cliffs of Inimore.* (560) |

| **REFERENCE SOURCE** | **REFERENCE DESCRIPTION** | **NOTES** (direct quotations extracted from references are *in italics*) |
|---|---|---|
| The Statistical Accounts of Scotland | Campbell, Donald, Rev. "Parish of Kilfinichen and Kilviceuen, comprehending the Quoad Sacra Parish of Iona, in the Island of Mull, Presbytery of Mull, Synod of Argyle." *The Statistical Account of Scotland, vol. 7, Renfrew-Argyle.* Edinburgh: William Blackwood and Son, 1845. | *Geology and Mineralogy.-A portion of the parish is composed of rocks of the trap and oolite formations, and they even form part of many of the high hills. The primary strata are to be found in Ross, and in a small patch on the shores of Loch Scridain. Professor St Fond says that Benmore is composed of lava, and Jameson agrees pretty nearly with his observations. The lofty crags of the whole shores are composed of basalt and wacken strata, traversed by basaltic veins which run in very different directions, and contain much zeolite. The island of Innskenneth is composed of red-coloured sandstone and limestone, and on the shores of Gribun opposite, are to be found argillaceous sandstone and sandstone breccia. The same appearances are presented at* ***Carsaig****, where there is limestone, and where freestone is quarried of good quality. Jameson found the granite of Ross disposed in beds, and that it would split into rhombs, and, what is more uncommon, into columns not unlike basalt. Dr Walker, many years previous, observed the same disposition of the granite not only in Mull, but in many other parts of Scotland. The whole south side of Ross is formed of granite and unicaceous schistus, until it arrives upon a line with Bunessan, where the basaltic rock commences. Of this granite the Sceryvore light-house is being erected.* (303) |
| The Statistical Accounts of Scotland | Ibid. | *The shore [of Iona] is otherwise bare and rugged, and the strata do not differ from those already described. At a short distance, there are several islets and rocks entirely composed of red granite, which circumstance renders it probable that the island was formerly joined with the granite coast of Ross Mull.* (319) |
| Memoirs of the Geological Survey, Scotland | Lee, GW, Bailey, EB, et al. "The pre-tertiary geology of Mull, Loch Aline, and Oban: being a description of parts of sheets 35, 43, 44, 45 and 52 of the one-inch geological map of Scotland". *Memoirs of the Geological Survey, Scotland.* Edinburgh: His Majesty's Stationery Office, 1925. | *Among early geological explorers of Mull (Sheet 44), Abraham Mills was informed of the existence of sandstone at* ***Carsaig****, while Robert Jameson found a belemnite-bearing limestone near Auchnacraig Farm (Loch Don), and heard of another limstone with "Cornua ammonis" and shells near Duart Castle.*<br>*Macculloch, later ... traced outcrops of limestone and sandstone (Lias, Sheet 44) occurring in a general way beneath the "traps" on both sides of Loch Spelve and westwards in the Carsaig district ...* (59-60) |
| Memoirs of the Geological Survey, Scotland | Bailey, EB, Anderson EM, et al. "The Geology of Staffa, Iona, and Western Mull: a description of sheet 43 of the Geological Map". *Memoirs of the Geological Survey, Scotland*. Edinburgh: HMSO, 1925. | *GRANITE--THE total land area of the Ross of Mull granite is about 20 square miles. The rock varies in colour from pale to deep red, and does not show prominent feldspar phenocrysts ... The following is a list of some of the instances of different types of construction in which Ross of Mull granite is known to have been used ... Iona Cathedral. The older part of this cathedral and the nunnery are mainly constructed of granite and flags, which are interbuilt without much dressing, but according to a definite plan. The pillars and facings are of sandstone. The granite is Ross of Mull granite, which might have been got from local boulders. In reconstructing the cathedral, the contractors followed the style of the original, and granite was obtained from the mainland Black Island Quarry ...* |

| REFERENCE SOURCE | REFERENCE DESCRIPTION | NOTES (direct quotations extracted from references are *in italics*) |
|---|---|---|
| Memoirs of the Geological Survey, Scotland | Ibid. | *FLAGSTONES--Metamorphic flagstones have been quarried on a small scale in the Ross of Mull for roofing and flooring the recently restored Iona Cathedral. Two notes on this subject may be quoted from Dr. Clough. The first was published in the Explanation of Sheet 35 (rgrl), and deals with a locality on the south coast. "Wishes have been expressed (Igog) to use the spangled flaggy mica schists of the Moine Series for roofing slates for the restored Iona Cathedral in lieu of the black slates at present used. A peculiar beauty does indeed attach to these spangled schists, but it would be very difficult to get even a moderate supply without going to great expense, for sufficiently thin beds are but sparsely scattered in different positions in the series. Prospecting for the flags has recently been carried on, on the coast about 300 yards west-south-west of Dun a' Ghaird [Dtin nan Ge&rd], but it has not been followed up by quarrying. Indications of former workings are said to be visible in this locality."*<br>*The second note is dated 1910, and refers to a locality on the north coast, a quarter of a mile west of the pier, half a mile west north-west of Bunessan. It runs: " Scars slightly quarried for new parts of Iona Cathedral, especially, it is said, for flooring."* |
| Royal Commission on the Ancient and Historical Monuments of Scotland | RCAHMS. "Mull, Tiree, Coll & Northern Argyll (excluding the Early Medieval & later monuments of IONA)". *Argyll: an inventory of the monuments, vol.3.* Edinburgh: Her Majesty's Stationery Office, 1980. | *Old Quarries, **Carsaig** Bay, Mull. Sandstone of Jurassic age suitable for building purposes is found widely in south-east Mull, the most conspicuous exposures occurring in the sea-cliffs on each side of **Carsaig** Bay, where they have an average thickness of 60 m. The stone varies from pale green to buff in colour and is generally fine-grained, but possesses poor weathering-qualities. The main centre of quarrying appears to have been near Rub' a' Chromain, about 2km SW of the head of the of the bay, where drill-holes, evidently dating from the most recent period of activity, can be seen at the foot of the cliff face. The stone must have been transported from the site by sea, but there are no visible remains of a jetty. About 50 m NE of Rubh' a' Chromain, and within the main quarry-area, there is a spacious cave, known as the Nuns' Cave, which was probably utilized by the quarrymen as a shelter and work-place.*<br>*Stone from this locality appears to have been quarried for use on Iona as early as the 12th century, and most of the later medieval buildings on that island, and several in Mull and Lorn, are constructed of the same material. In 1795 it was reported that 'free-stone is also found in **Carsaig** of excellent quality. Some of it is used by several gentlemen in the county for their houses'. The quarry was still being worked shortly before the middle of the 19th century, and was briefly reopened in 1875 to supply stone for restoration work at Iona Abbey.* (248-9) |
| Royal Commission on the Ancient and Historical Monuments of Scotland | Ibid. | Other buildings that may have been constructed with **Carsaig** sandstone: Old Parish Church, Kilvickeon, Mull (dressings); Caibeal Mheamhair, Laggan, Mull (quoins and dressings); Aros Castle, Hall-House, Mull (dressings in East wall); Duart Castle, Mull (later work); Moy Castle, Mull (quoins and dressings); Chapel Inch Kenneth, Mull (dressings). |
| Royal Commission on the Ancient and Historical Monuments of Scotland | Ibid. | *Nuns' Cave, **Carsaig**, Mull. … There are also two masons' marks [carved into the West wall of the cave], probably carved by men working the nearby quarries in the 18th or 19th century …* (159) |

| REFERENCE SOURCE | REFERENCE DESCRIPTION | NOTES (direct quotations extracted from references are *in italics*) |
|---|---|---|
| Memoirs of the Geological Survey, Scotland | Ibid. | ***Carsaig*** *Bay. The grandest display of the Middle Lias in Mull is seen in the Carsaig district. The lower fossiliferous horizon is not well exposed, but the upper white sandstone averages 200ft in thickness, and forms the lower portion of the cliffs on either side of* ***Carsaig*** *Bay. The peculiar feature alluded to, namely the presence of large balls, is here remarkably developed. These balls, which reach four feet in diameter, are generally made up of sandstone slightly harder than the main mass, and weathering brown, with a cellular surface. Between tide marks below the Nun's Pass, they stand out like small haystacks on a field. Occassionally, these balls are made up of softer materials and show as niches hollowed out in the face of the cliff. This sandstone was formerly quarried, and, as suggested by Prof. Judd, could probably be extensively worked for building purposes were it not for the inaccessibility of the Carsaig shores.* (93-4) |
| Memoirs of the Geological Survey, Scotland | Ibid. | *Middle Lias Sandstone (Scalpa Beds--Sheets 44). According to tradition, the old sandstone quarries, shown by a note on the Map near the Nun's Pass, west of* ***Carsaig****, supplied freestone used in the ecclesiastical buildings of Iona. The sandstone averages about 200ft in thickness, and might easily be worked again, if shipping were more easy.*<br>*The following is a list of exposures of the same sandstone in the eastern corner of Mull which might perhaps meet the local demand, should such arise. The available thickness sometimes reaches 100ft:--*<br>*Cliff parallel with coast between Port Donain and Port nam Marbh*<br>*On both sides of Loch Don Anticline, north of Gualachaolish Farm*<br>*On west of Loch Don Anticline, in Gleann Rainich: (1) between path and stream west of Cnoc na Moine; and (2) in stream north-west of south end of Loch a' Ghleannain*<br>*Along Abhuinn Lirein, a quarter of a mile above Oakbank House*<br>*Pier, Duart Bay* (125) |
| Royal Commission on the Ancient and Historical Monuments of Scotland | RCAHMS. Iona. *Argyll: an inventory of the monuments, vol.4.* Edinburgh: Her Majesty's Stationery Office, by Pillans & Wilson Ltd., 1982. | *Other buildings that may have been constructed with* ***Carsaig*** *Sandstone: St Oran's Chapel and Reilig Odhrain, Iona (dressings and quoins); St Ronan's Church, Iona.* [This series has not been exhausted, particularly for other uses of Carsaig sandstone] |
| Pevsner Architectural Guide | Walker, Frank Arneil. *The buildings of Scotland: Argyll and Bute*. Penguin Books: London, 2000. | *A quarrying method that was often used involved the use of wooden wedges which were inserted into cracks or holes when dry and allowed to swell as the tide rose. The method was used at* ***Carsaig****, on Mull…* (10) |
| Pevsner Architectural Guide | Ibid. | [Sandstone quarried at **Carsaig** Bay] *is a greenish or buff, fine-grained sandstone of Lower Jurassic age which was widely used, particularly on Iona, but also in many other buildings on the mainland. It can be seen in the C13 part of Ardchattan Priory and in Mull in several buildings around Loch Buie.* (11) |

| REFERENCE SOURCE | REFERENCE DESCRIPTION | **NOTES** (direct quotations extracted from references are *in italics*) |
|---|---|---|
| **Historical Maps** | | |
| Ordnance Survey Maps | National mapping authority for Great Britain | OS 1881 and 1900 Map: 'Quarries' marked, no differences identified between the two maps; OS present day 'Quarries (dis)' marked, indicating the quarry is no longer active. |
| **BGS Geology Maps** | | |
| BGS Field Slip | British Geological Survey. *Field Slip of ARGYLL 119 NW-(E) and NW-(W) on 1900 OS Map.* Unpublished, 1902-12. | *Cliffs of white sandstone with cannonball concretions*<br>*Sandstone flat coarse alveolar weathering* |

# Appendix 3 Petrographical analyses

Each numbered note below relates to a superscript number in the petrographic descriptions contained in the following pages.

1 The determination of stone type follows the classification and nomenclature of the BGS Rock Classification Scheme.

2 The 'visual' determination of stone colour is based on a simple assessment with the unaided eye in natural light. The 'Munsell' determination is obtained by matching the stone colour to one of the coloured patches in a Munsell Rock Colour Chart; each patch has a unique colour and a unique code (the 'Munsell code'), which incorporates values for hue and chroma. In stones displaying variable colour, both the 'visual' and 'Munsell' determinations record the colour deemed by the geologist to be most representative. The determination of stone colour is made on a broken (not sawn), dry surface.

3 A simple, non-quantitative assessment of the degree to which the stone is cohesive. This property is recorded in terms of four conditions, each representing one segment of a continuum: *strongly cohesive*, *moderately cohesive*, *moderately friable*, and *very friable*. The grains in a *strongly cohesive* stone cannot be disaggregated by hand, whereas the grains in a *very friable* stone can be readily disaggregated by hand.

4 A record of whether the distribution of granular (detrital) constituents in the sample is essentially isotropic (uniform) or anisotropic (non-uniform). The type of anisotropic fabric is recorded.

5 A record of the identity and relative proportions of all granular (detrital) and intergranular (authigenic materials and pore space) constituents currently in the stone. The proportions are estimates, expressed in %, which are based on a visual assessment of the whole thin section area.

6 The terms are those used for grain-size divisions in the BGS Rock Classification Scheme.

7 A simple, non-quantitative assessment of the degree to which detrital constituents display similarity in terms of physical characteristics (in particular the size and shape of grains).

8 A simple, non-quantitative assessment of the degree to which detrital constituents are abraded.

9 A simple, non-quantitative assessment of stone permeability, presented as one of five conditions (*very low*, *low*, *moderate*, *high*, *very high*) expressed relative to a nominal 'average' permeability in building stone sandstones. The assessment is based on: (i) a water bead test; (ii) the proportion of pore space in the stone; (iii) a visual assessment of the degree to which pore spaces appear connected in the thin section.

10 A record of the type and extent of authigenic mineral cement that acts to bind detrital grains, as observed in thin section. *Isolated* means the cement occurs in discrete locations (e.g. as overgrowths on individual detrital grains) that are typically not connected in the plane of the thin section. *Discontinuous* means the cement is formed in patches, each of which typically encloses several to many detrital grains. *Continuous* means the cement is more-or-less connected across the thin section.

11 A record of the evidence observed in thin section for mineral alteration that occurs in the stone when it is near the ground surface. Such alteration processes typically begin before stone is quarried, but some may continue, or be initiated, after stone is extracted from the ground.

# Sample S54103: Carsaig quarry (probably from the 'cliff-face' area)

## Hand specimen observations

**Stone type** [1] (general classification): sandstone
**Stone colour** [2] – fresh stone: very light yellowish grey
**Stone colour** [2] – weathered stone: not applicable
**Stone colour** [2] – exterior surface: light grey
**Stone cohesion** [3] – fresh stone: moderately cohesive
**Stone cohesion** [3] – weathered stone: not applicable
**Stone fabric** [4]: uniform (some orientated grains)
**Distinctive features**: none

## Thin section observations

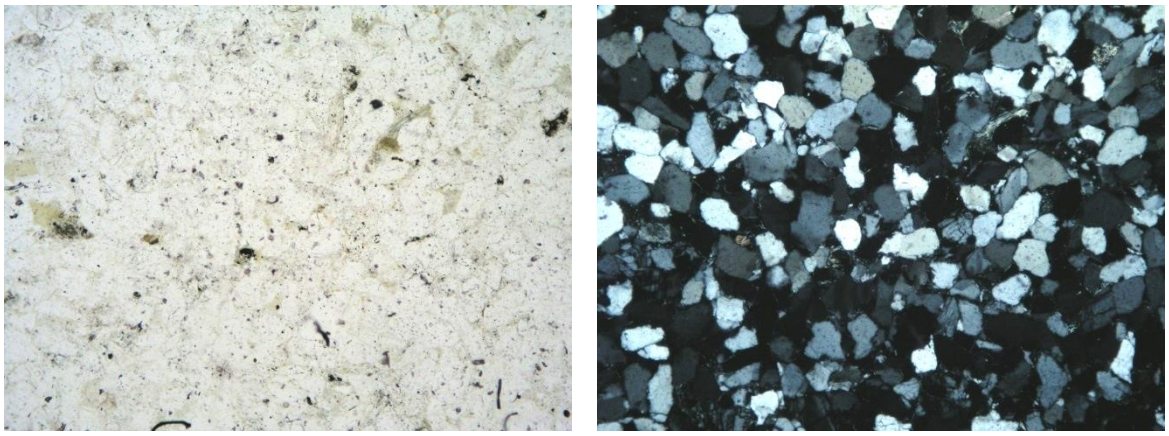
**Stone constituents** [5]:

| *Granular (detrital) constituents* | | *Intergranular constituents* | |
|---|---|---|---|
| Quartz | 74% | Silica (overgrowth) | 4% |
| Feldspar | 3% | Feldspar (overgrowth) | 0% |
| Rock fragments | 1% | Carbonate | <1% |
| Mica | 1% | Iron/manganese oxide | 1% |
| Opaque material | <<1% | Clay | 7% |
| Other | <<1% | Hydrocarbon | 0% |
| Intragranular pores | 1% | Intergranular pores | 7% |

**Stone type** [1] (detailed classification): quartz-arenite
**Grain-size** [6]: fine-sand-grade to medium-sand-grade
**Grain sorting** [7]: moderately well sorted
**Grain roundness** [8]: angular to sub-rounded
**Stone permeability** [9]: moderate to high
**Cement distribution** [10]: silica cement discontinuous
**Supergene changes** [11]: weak dissolution of feldspars

## Comments

The detrital grains are bound by silica cement, but a very thin coating of clay minerals around on some grai8n surfaces reduces the cohesion of the sandstone.



Thin section photographs of sample S54103. The thin section was prepared around one century ago, and is not impregnated with blue resin; consequently, natural pore space and some other details are difficult to discern. The same area of the thin section has been photographed in plane-polarised light (left) and in cross-polarised light (right) to show more detail. In the left image, white grains are mainly quartz and pale green patches between the quartz grains are clay minerals; black spots are mainly artefacts introduced during the making of the thin section, though some will be natural iron oxide minerals. The field of view is c.3.3 mm wide.

# Sample ED11283: Carsaig quarry (foreshore area)

## Hand specimen observations

**Stone type** [1] (general classification): sandstone
**Stone colour** [2] **–** fresh stone: brownish grey
**Stone colour** [2] **–** weathered stone: not applicable
**Stone colour** [2] **–** exterior surface: brownish green
**Stone cohesion** [3] – fresh stone: strongly cohesive
**Stone cohesion** [3] – weathered stone: not applicable
**Stone fabric** [4]: irregular lamination
**Distinctive features**: none

## Thin section observations

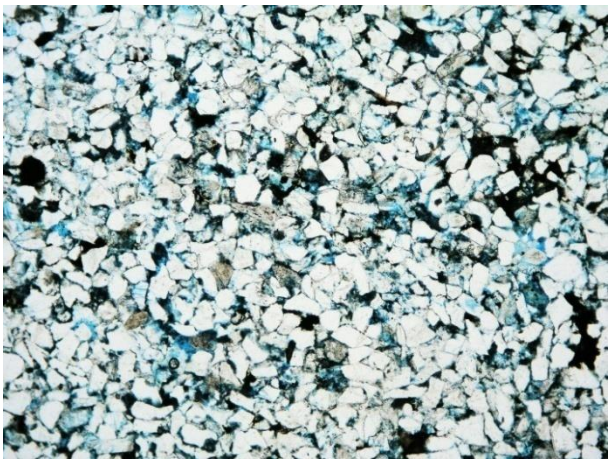
**Stone constituents** [5]:

| *Granular (detrital) constituents* | | *Intergranular constituents* | |
|---|---|---|---|
| Quartz | 64% | Silica (overgrowth) | 2% |
| Feldspar | 4% | Feldspar (overgrowth) | 0% |
| Rock fragments | 2% | Carbonate | 7% |
| Mica | 1% | Iron/manganese oxide | 5% |
| Opaque material | 0% | Clay | 2% |
| Other | <1% | Hydrocarbon | 0% |
| Intragranular pores | 2% | Intergranular pores | 10% |

**Stone type** [1] (detailed classification): subfeldspathic-arenite
**Grain-size** [6]: fine-sand-grade
**Grain sorting** [7]: very well sorted
**Grain roundness** [8]: angular to sub-rounded
**Stone permeability** [9]: moderate to high
**Cement distribution** [10]: silica cement discontinuous; calcite cement isolated
**Supergene changes** [11]: weak dissolution of feldspars; moderately remobilised iron; moderate dissolution of rock fragments

## Comments

1) Well rounded grains of the mineral zircon appear in trace (<<1%) proportion.



Thin section photograph of sample ED11283. The image was taken in plane-polarised light, and the field of view is c.3.3 mm wide. White grains are mainly quartz, grey and brown grains are mainly feldspar and rock fragments, black patches are mainly iron oxide minerals and organic matter. Pore space appears blue.

# Sample ED11286: Iona Nunnery (fragment, arched doorway between cloister and nave)

## Hand specimen observations

**Stone type** [1] (general classification): sandstone
**Stone colour** [2] **–** fresh stone: brownish grey
**Stone colour** [2] **–** weathered stone: greyish buff
**Stone colour** [2] **–** exterior surface: greyish buff
**Stone cohesion** [3] – fresh stone: not applicable
**Stone cohesion** [3] – weathered stone: moderately cohesive
**Stone fabric** [4]: irregular lamination
**Distinctive features**: none

## Thin section observations

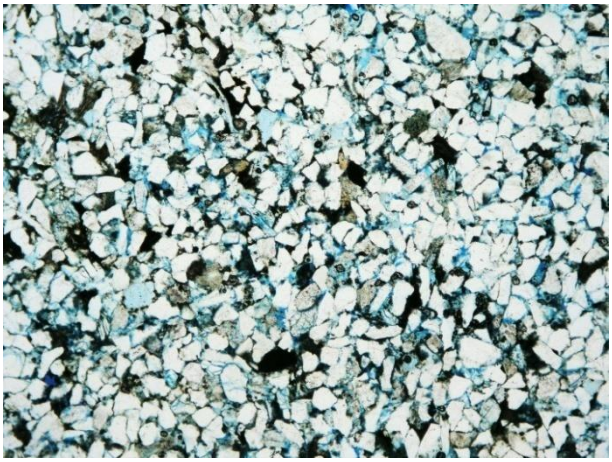
**Stone constituents** [5]:

| *Granular (detrital) constituents* | | *Intergranular constituents* | |
|---|---|---|---|
| Quartz | 68% | Silica (overgrowth) | 2% |
| Feldspar | 5% | Feldspar (overgrowth) | 0% |
| Rock fragments | 2% | Carbonate | 1% |
| Mica | 1% | Iron/manganese oxide | 4% |
| Opaque material | 0% | Clay | 2% |
| Other | <1% | Hydrocarbon | 0% |
| Intragranular pores | 5% | Intergranular pores | 10% |

**Stone type** [1] (detailed classification): subfeldspathic-arenite
**Grain-size** [6]: fine-sand-grade
**Grain sorting** [7]: very well sorted
**Grain roundness** [8]: angular to sub-rounded
**Stone permeability** [9]: moderate to high
**Cement distribution** [10]: silica cement discontinuous
**Supergene changes** [11]: weak dissolution of feldspars; moderately remobilised iron; moderate dissolution of rock fragments

## Comments

1) Well rounded grains of the minerals zircon and tourmaline appear in accessory (<<1%) proportions.



Thin section photograph of sample ED11286. The image was taken in plane-polarised light, and the field of view is c.3.3 mm wide. White grains are mainly quartz, grey and brown grains are mainly feldspar and rock fragments, black patches are mainly iron oxide minerals and organic matter. Pore space appears blue.

# Sample ED11279 (P5): sandstone block at Carsaig pier

## Hand specimen observations

**Stone type** [1] (general classification): sandstone
**Stone colour** [2] **–** fresh stone: very light grey
**Stone colour** [2] **–** weathered stone: not applicable
**Stone colour** [2] **–** exterior surface: light greenish grey
**Stone cohesion** [3] – fresh stone: strongly cohesive
**Stone cohesion** [3] – weathered stone: not applicable
**Stone fabric** [4]: irregular lamination
**Distinctive features**: none

## Thin section observations

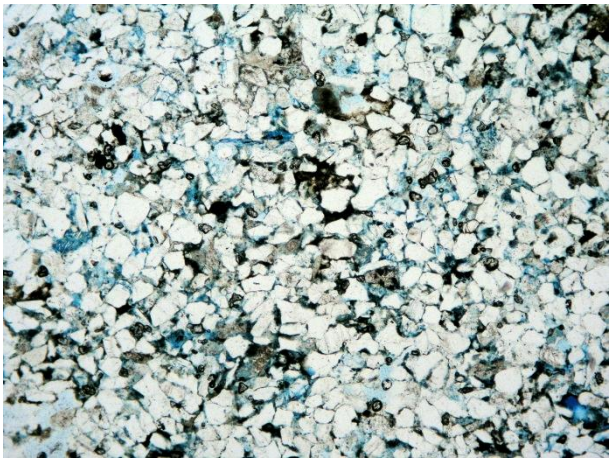
**Stone constituents** [5]:

| *Granular (detrital) constituents* | | *Intergranular constituents* | |
|---|---|---|---|
| Quartz | 70% | Silica (overgrowth) | 4% |
| Feldspar | 4% | Feldspar (overgrowth) | 0% |
| Rock fragments | 1% | Carbonate | 1% |
| Mica | 1% | Iron/manganese oxide | 3% |
| Opaque material | <1% | Clay | 8% |
| Other | <<1% | Hydrocarbon | 0% |
| Intragranular pores | 2% | Intergranular pores | 5% |

**Stone type** [1] (detailed classification): subfeldspathic-arenite
**Grain-size** [6]: fine-sand-grade
**Grain sorting** [7]: well sorted
**Grain roundness** [8]: angular to sub-rounded
**Stone permeability** [9]: moderate to high
**Cement distribution** [10]: silica cement continuous
**Supergene changes** [11]: weak dissolution of feldspars; moderate dissolution of rock fragments

## Comments

None



Thin section photograph of sample ED11279. The image was taken in plane-polarised light, and the field of view is c.3.3 mm wide. White grains are mainly quartz, grey and brown grains are mainly feldspar and rock fragments, black patches are mainly iron oxide minerals and organic matter. Pore space appears blue.

# Appendix 4 Closest-matching, commercially available stones

A BGS Building Stone Assessment is usually performed in three stages.

(i) The sample of 'original' stone is first subjected to a detailed petrographic examination, to establish the range and character of its intrinsic properties.

(ii) The range of properties is then compared with those of stone samples held in the BGS Collection of UK Building Stones, to constrain the source of the stone. Historical records (if available), and the likelihood that the stone was sourced locally or imported, are also taken into account.

(iii) Finally, the closest-matching currently available stones are identified. If the quarry from which the stone was sourced originally has been identified, and is still open, it will usually provide the closest-matching stone. If the quarry from which the stone was sourced originally has not been identified, or is closed, the closest-matching currently available stones are identified by comparing the properties of the original stone with those of samples of currently available stones held in the BGS Collection of UK Building Stones.

Comparing stone properties to identify the source and/or the closest-matching stones is known as stone matching. Further details of the methodology applied to stone matching are provided in Appendix 2.

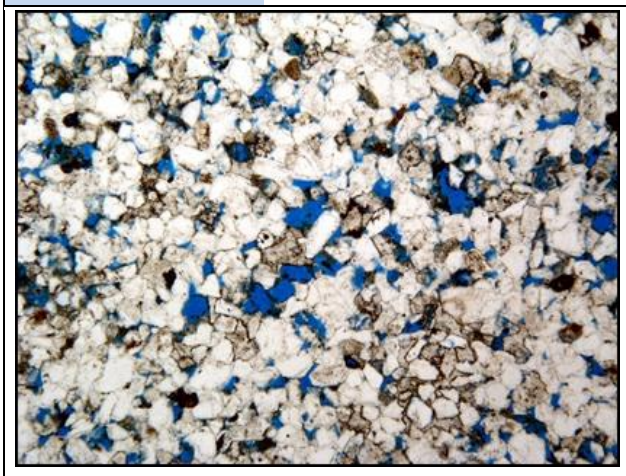
Please keep in mind the following points when considering the list of closest-matching stones.

- The list of closest-matching stones has been derived by comparing the stone to be repaired with samples of stone obtained from currently active quarries. The characteristics of stone from a quarry source can vary over time and from place to place within the quarry; there is therefore no guarantee that a sample of quarry stone held by BGS is representative of the stone currently being supplied by the quarry.
- One or more samples of stone should be obtained from a quarry operator prior to stone specification, to confirm the appearance and character of the stone currently being supplied.
- The mention of specific stone types should not be taken as an endorsement, or otherwise, of the quality of a particular product.
- Specific functional requirements, block dimension requirements, and the ability of a stone to give a particular masonry tooled finish should be discussed with the supplier prior to specification.

The inclusion of any stone within the list of 'closest-matching stones' does not guarantee that it will weather sympathetically or co-exist harmoniously with the original stone. The BGS Building Stone Assessment is designed to **maximise the likelihood** that a replacement stone and the original stone will be compatible. However, the small number and range of currently available stones compared to those that have been used in the past mean that it is commonly not possible to identify an ideal match. Furthermore, several factors – including the highly variable character of natural stone, the wide range of natural and human factors that can influence stone decay, and the wide range of environmental settings and conditions that masonry can be subjected to – mean that it is not possible to predict with certainty how replacement stone will perform in masonry.

## Spynie sandstone

| | |
|---|---|
| **Colour:** | White to very light greyish buff |
| **Stone fabric:** | Uniform |
| **Grain-size:** | Fine-sand-grade |
| **Permeability:** | Low |
| **Distinctive features:** | Spynie sandstone can contain small (<1mm), scattered iron/manganese nodules |
| **Comments:** | Spynie sandstone is known to withstand well decay caused by salt related to coastal settings. |

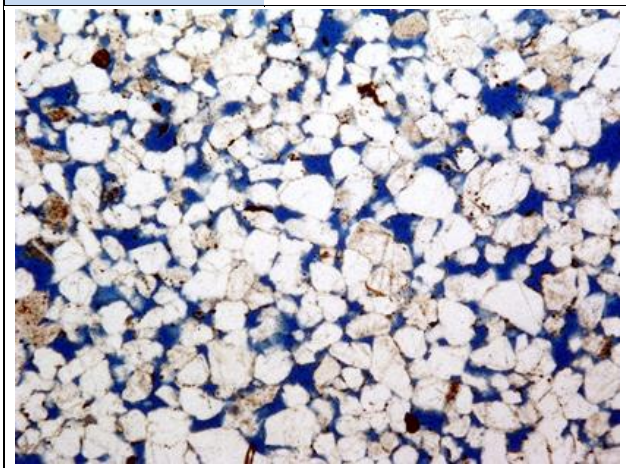


**Supplier details:**

Gavin Tennant
Moray Stone Cutters
Tennants of Elgin, Ltd
Brumley Brae
Elgin
IV30 5PP
Tel: 01343 552767
Email: sales@tennantselgin.com
Web page: www.tennantselgin.com

## Cullalo sandstone

| | |
|---|---|
| **Colour:** | Very light grey to light buff |
| **Stone fabric:** | Uniform |
| **Grain-size:** | Fine-sand-grade to medium-sand-grade |
| **Permeability:** | High |
| **Distinctive features:** | None |
| **Comments:** | None |

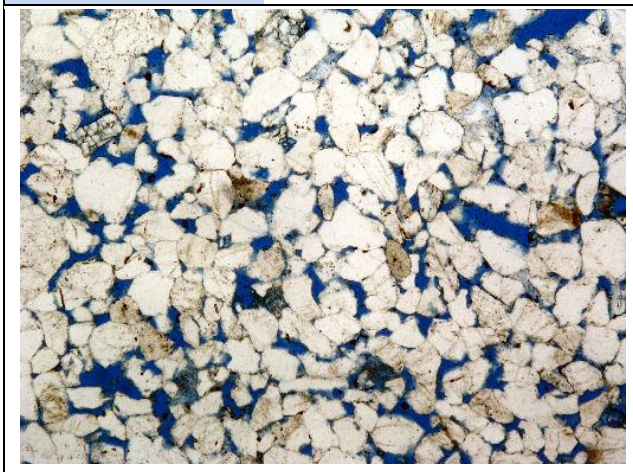


**Supplier details:**

Tradstocks
Dunaverig
Thornhill
Stirling
FK8 3QW
Tel : 01786 850400
Email: info@tradstocks.co.uk
Web page: www.tradstocks.co.uk

## Hazeldean sandstone

| | |
|---|---|
| **Colour:** | White to light grey with buff and pink tones |
| **Stone fabric:** | Uniform (with some aligned grains indicating the bedding orientation). |
| **Grain-size:** | Fine-sand-grade to medium-sand- grade |
| **Permeability:** | Moderate to high |
| **Distinctive features:** | None |
| **Comments:** | Samples to represent the range of stone colours currently being supplied by the quarry should be obtained to assess which provides the closest match in terms of appearance. The light grey to light buff stone should be the variants to use for this particular case. |



**Supplier details:**

Hutton Stone Co Ltd.
Masons & Stone Merchants
West Fishwick
Berwick-upon-Tweed
TD15 1XQ

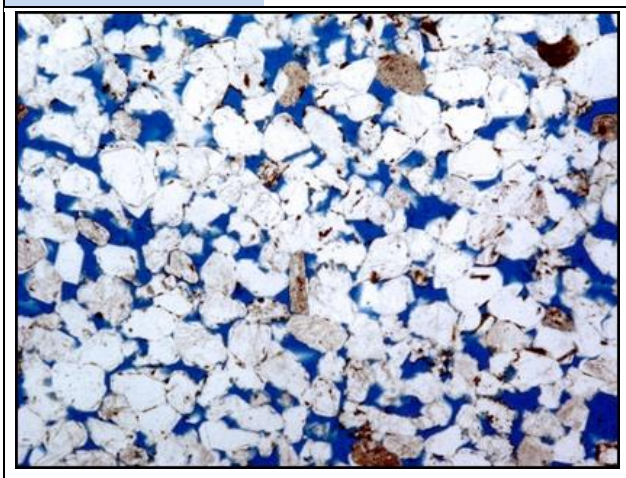
Tel : 01289 386056

Email :huttonstone@aol.com

Web page: www.huttonstone.co.uk

## Clashach sandstone

| | |
|---|---|
| **Colour:** | Typically variegated on the scale of individual blocks, with light buff (almost white), yellowish buff to brown, orange and pink tones. Blocks of stone with uniform colour are also supplied, and the current availability of such stone should be discussed with the supplier. |
| **Stone fabric:** | Uniform |
| **Grain-size:** | Medium-sand-grade |
| **Permeability:** | High |
| **Distinctive features:** | Variegated colour |
| **Comments:** | Only the white to very light buff variants of Clashach sandstone should be used. |



**Supplier details:**

Gavin Tennant
Moray Stone Cutters
Tennants of Elgin, Ltd
Brumley Brae
Elgin
IV30 5PP

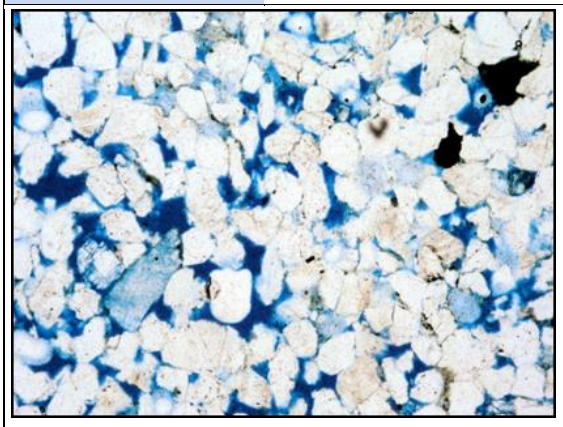
Tel: 01343 552767

Email: sales@tennantselgin.com

Web page: www.tennantselgin.com

## Darney sandstone

| | |
|---|---|
| **Colour:** | Light buff (sold as 'Darney Cream sandstone') to buff with orangeish banding (sold as 'Darney Gold sandstone'). One bed produces white sandstone. |
| **Stone fabric:** | Mostly uniform, occasionally with faint parallel bedding. The bedding orientation is indicated by aligned mica flakes. |
| **Grain-size:** | Fine-sand-grade to medium-sand-grade |
| **Permeability:** | High |
| **Distinctive features:** | The stone can contain iron-rich nodules. Iron oxide banding is a particular feature of Darney Gold sandstone. |
| **Comments:** | The Darney Cream and Darney White sandstone variants should provide a better appearance match than Darney Gold, which may be too strongly coloured. |



**Supplier details:**

Stancliffe Stone
Keypoint Office Village
Keys Road
Nixs Hill Industrial Estate
Alfreton
Derbyshire
DE55 7FQ

Tel: 0845 302 0702

Email: info@stancliffe.com

Web page: www.stancliffe.com